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(54) **APPARATUS AND METHOD FOR MICROWAVE DETERMINATION OF AT LEAST ONE PHYSICAL PARAMETER OF A SUBSTANCE**

VORRICHTUNG UND VERFAHREN ZUR BESTIMMUNG WENIGSTENS EINER PHYSIKALISCHEN GRÖSSE EINER SUBSTANZ MITTELS MIKROWELLEN

APPAREIL ET PROCEDE DE DETERMINATION PAR MICRO-ONDES D'AU MOINS UN PARAMETRE PHYSIQUE D'UNE SUBSTANCE

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Description

Field of the invention

[0001] The present invention concerns a method and apparatus for determining at least one physical parameter of an object by means of transmitting microwaves towards the object and analysing the co-polar and cross-polar transmitted and reflected microwaves.

Background of the invention

[0002] It is well known that during processing of a variety of products such as wood, tobacco and food the moisture content in the product plays an important role before the product enters the final stage in the production.

[0003] When the moisture content is measured by using microwave radiation, the microwaves interact with the water molecules in the substance being measured. Due to the dipole character of the water molecule, the microwave fields interact with the molecules resulting in a rotational and translational motion of the molecules causing heat absorption of the incident energy. By measuring the attenuation (loss of energy) of the microwaves along with the phase shift (loss of velocity) of the microwaves the moisture content of the material can be accurately determined. This is typically done by transforming the output signal to an electrical signal. The attenuation and phase shift within a material can be used to calculate the dielectric properties of that material. The dielectric properties of a material are usually expressed by the relative complex permittivity, $\varepsilon = \varepsilon' + j\varepsilon''$, where ε' is the dielectric constant that represents the ability of a material to store electric energy, and ε'' is the loss factor representing the loss of electric field energy in the material. By knowing both ε' and ε'' one can calculate water content and density of the material according to published formulae.

[0004] Furthermore, other physical parameters such as fat, protein and salt can be determined for example by using more than one frequency and isolating the absorption effects due to water and absorption due to the presence of salt Ions which are governed by the difference in the frequency dependence of the two loss mechanisms. By doing repeated analysis with the device and by comparing results obtained by using conventional methods, calibration can be achieved.

[0005] Hitherto known methods using microwaves generally only measure moisture content but not other physical parameters such as fat, protein and salt. For example, no device has been made to measure fat content using non-contact microwave techniques. A hand held device has been made that estimates fat content using microwaves. However, the device needs to be in firm contact with the substance to be measured and actually measures the moisture content. The device is precalibrated and calculates the fat content from the measured moisture content.

[0006] Other systems and methods have been developed for measuring the moisture content of material. One is to use a hand held instrument, similar to the one mentioned above, a so called "stripline" sensor. The instrument is placed on the material in such a way that the stripline is in close contact with the material. Microwaves are then generated and fed along the stripline, and the attenuation is measured in the stripline. The attenuation or loss is then converted to water content. This method is a surface measurement. To obtain overall moisture content in bulk material, it is necessary to measure at several places, and turn the object around. The average value is then used as an indicator.

[0007] In another device the material is placed between the transmitting and receiving antennas of a microwave transmission system and by comparing the output signal from the material with the source signal the material properties can be deduced.

[0008] In US patent no. 4,578,998, there is disclosed a microwave system using different polarisation of signals. Two radiators are used to measure across a sheet material by utilizing two different polarisations so that signal interchange between them is avoided. The polarisation is in other words used to distinguish between radiators.

[0009] The problem with the disclosure of US patent no. 4,578,998 is that the measured signal comprises both the attenuation through the material and also reflections from microwaves bouncing off surrounding material, which is not being examined. This will introduce errors into the result.

[0010] The disadvantage of using the hand held contacting instrument is that it is a surface measurement of a bulk material. Therefore it is time consuming to obtain a measurement for the material as a whole due to the fact that one has to measure on various spots around the material and also due to the inconvenience of having a human operating the instrument by placing the sensor in contact with the material while measuring it: This can cause errors since people will never operate the instrument in exactly the same way.

General description of the invention

[0011] It is an object of the present invention to improve the above mentioned methods by providing a method and an apparatus to measure at least one physical parameter of a substance, such as moisture and fat content of bulk material. This is done by utilizing the polarisation to create a transmission path through the sample, wherein a microwave beam is transmitted through the material to be measured and only a reflection of a predetermined polarity of the transmitted waves is detected. This has the advantage that only the signal that has travelled through the material is measured. This is accomplished by providing a polarising plate so that only cross-polarised microwaves, which pass through the

substance are detected and co-polar reflections from surrounding structures are excluded. This increases therefore the sensitivity and accuracy of the measurement. Accordingly, only those waves are received that have bounced off the polarising plate after passing through the substance being measured. When the system is set up to detect cross-polar reflections it can be ensured that the measured microwaves have passed through the object twice before being detected. When the system is set up to detect co-polar reflections the distance of the surface of the material from the aperture of the receiver antenna can be determined and this can be related to the depth of the material by comparing with co-polar reflections when no material is present.

[0012] According to the first aspect the present invention relates to an apparatus as defined in claim 1.

[0013] Further, control electronics are preferably provided to control the source. The polarizer may be a plate with a plurality of parallel metallic wires positioned in the horizontal plane of the polarisation plate for rotating at least a part of the transmitted waves. These wires can be supported by a non-reflecting medium such as a plastic material. The bottom layer of the polarization plate is a reflecting material such as a metallic plate. As the microwaves hit the polarisation plate part of them hits the wires that rotate the polarisation and a part passes between the wires through the supporting material until it is reflected from the bottom plate. The bottom plate reflects the microwaves according to the law of reflection, wherein a part of these reflected microwaves hit the wires that rotate the polarisation. With a properly thickness of the polarisation plate, i.e. interval between the wires and the bottom plate, the "second" polarisation can be the same as the "first" polarisation. Preferably, this interval is 1/4 λ, where λ, is the wavelength of the microwaves, or generally (1/4+n) λ with n as an integer. This is however typically the case when air is between the wires and the reflecting plate. However, this thickness ratio is different when there is a material between the wires and the reflecting plate, and depends on the dielectric properties of the material. The rotated polarisation is received with a receiver that converts the microwaves to an electrical signal. This polarisation of this received microwave is 90° rotated with respect to the transmitted microwaves. The receiver can for example be an antenna or a dipole.

[0014] The frequency of the time-dependent electrical source signal depends on whether only one parameter is measured, such as moisture, or more parameters are measured, such as moisture and salinity. This is due to the different characteristic of the water and salinity molecules and their resonance frequency. In one embodiment the time dependent electrical signal has a frequency in a sequential cyclic, i.e, first the frequency is for measuring the moisture and the second, different frequency, is for measuring the salinity. Therefore the time-dependent electromagnetic field has at least one frequency.

[0015] For determining at least one physical parameter of the object, which can be the moisture content and/or the density of the object, it may be useful to use a reference channel. In one embodiment the apparatus is provided with a coupler for dividing the electrical signal between the transmitter which can be a transmitting antenna and the receiver, wherein the part of the electrical signal directed towards the receiver passes trough a reference channel and is used as a reference signal. Preferably half of the source signal passes through the reference channel and the other half to the transmitting antenna.

[0016] The measurements on the object can be as the object is in a rest position or as the object is being conveyed by a conveying means such as a conveyor belt. The transmitting and the receiving antennas will normally be in close proximity at a suitable position above the object with their radiation patterns directed at the object. For attenuation measurements the antennas are with respect to each other orthogonally polarized.

[0017] Furthermore, to measure the permittivity constant of the material, it is important to be able to determine the thickness of the material. One way of measuring this is by implementing a second receiving antenna positioned above to the object with respect to the polarizer and close to the transmitting antenna. The co-polar signal therefore measures the difference in distance when no material is present and when material is present. Preferably, the polarity of the received microwave is in this case the same as of the transmitting microwaves. It is also possible to use ultrasound for the same purpose.

[0018] A further aspect of the present invention is to provide a method as defined in claim 11.

[0019] In one embodiment the time-dependent electrical signal from the source is split in two, partly passing through a reference channel and partly passing from the polarising plate to a receiving means, and thereafter the two signals are added again. The summed signal is used as a reference signal with a reference phase and a reference level, for example when no material is present on the polarising plate. Any deviation from this reference phase and reference level when an object is placed on the polarizer is used to determine relative complex permittivity of the object. A shift in the reference phase or frequency can be used to calculate the dielectric constant ε', and a shift in the reference level can be used to calculate the loss factor ε'' of the object. Another parameter which is important when calculating ε' and ε'' is thickness of material which microwaves travel through. This parameter can be determined for example by using a second receiving means positioned opposite to the object with respect to the polarizer. The second receiving means would preferably be adjusted so that it detects microwaves of the same polarity as the transmitted microwaves. Therefore the part of the microwaves that is reflected from the object is determined and compared to a reference signal, for example a signal

without any object, and the phase shift from this reference signal is used to determine the height of the object. By knowing the distance between the aperture and the polarising plate, and the angle of radiation from the transmitting hom, the effective measurement area can be determined. Together with the thickness, the volume is thus calculated.

[0020] The transmitted microwaves are linear polarized and the polarisation part of the reflected wave that the receiving means detects is 90° polarized with respect to the transmitted microwave. This is to ensure that only the part of the transmitted waves which have passed through the entire object is detected, wherein the polarizer is located under the object and therefore the microwaves with this polarisation must pass through the object. One way of measuring the phase change and attenuation change in a material is by using a reference channel. The sum of the signal from the reference channel and the signal reflecting of the polarizer, will be zero, with the aid of an adjustable attenuator and phase shifter in the reference channel when no material is present.

[0021] Furthermore, the moisture content can be used to determine the fat concentration of an object such as fish, where the buoyancy is known and constant, and therefore the relationship between fat and water in the body is established by an empirical formula. This could be achieved by using historical data.

Detailed description

[0022] In the following, the present invention, and in particular preferred embodiments thereof, will be described in greater detail in connection with the accompanying drawings in which,

FIG. 1 is a flow chart showing how one embodiment can be used with the method of the present invention to measure moisture content.

FIGS. 2a and 2b are schematic drawings of one embodiment of an apparatus, which can be used with the method of the present invention.

FIG. 3 is a schematic drawing of a second embodiment that can be used with the present invention for measuring moisture content. Furthermore, this embodiment also measures the depth and hence the density of the object or substance being measured.

FIG. 4 is a graph showing samples of the electrical response to the presence of an object or substance within the transmitted beam, which is used to calculate the density of the measured object and the wet mass of the measured object.

FIG. 5 shows one embodiment of the polariser.

FIG. 6 shows results from experiments with the apparatus

[0023] FIG. 1 is a flow chart showing how one embodiment of the apparatus can be used with the method of the present invention to measure moisture content.
The apparatus includes a microwave radiation source **1**, shown to the left of the coupler **2.** In a preferred embodiment the microwave radiation source **1** is a swept source that sequentially transmits microwaves with a frequency which changes preferably linearly with time over a specified frequency bandwidth. The source (or sources) may be arranged to transmit more than one centre frequency. The swept source **1** receives a signal from the switch **15** before sending a signal to the coupler **2.** The switch **15** determines which centre frequency is transmitted.

[0024] The signal from the swept source **1,** once amplified to an appropriate level, is then divided at the coupler **2,** with part of the signal passing through a reference channel to the receiver **7,** while the remaining signal passes to the transmit antenna **4** in the measurement channel. Preferably the signals that go to the two different directions are equal, each part being exactly 50% of the original signal.

[0025] It will be appreciated that the sample being measured can be replaced with a continuous flow of bulk material without departing from the principles of the present invention. For the purpose of this illustration the apparatus will be described only with a single sample to be measured.

[0026] The microwaves are directed at the sample by means such as transmitting antenna **4.** Alternatively, a planar antenna can be used for the same purpose.

[0027] The source signal **10a** is a very high frequency microwave signal which is frequency modulated by linearly sweeping the source oscillator from a frequency just below the centre frequency to a frequency just above it over a predetermined bandwidth. The preferred centre frequency for the source signal depends on the nature of the sample **14** and the number of frequencies depends on the number of physical parameters to be measured, such as moisture, salt or protein.

[0028] The source signal **10a** passes through the sample **14,** hits the polariser **5** and is reflected back. As the source signal **10a** has passed through the sample it is both attenuated and slowed. The extent of this attenuation is determined mostly by the loss factor ε'' of the material of the sample **14** encountered by the source signal. The degree to which the source signal is slowed is predominantly determined by the dielectric constant ε' of the material **14.**

[0029] As the source signal **10a** hits the polariser **5** the polariser **5** changes the polarisation of the signal to that of the receiver antenna **6.** The transmit antenna **4** and the receiver antenna **6** are essentially identical except that they will be orthogonally polarised. This means that any reflections off the sample, conveyer belt or con-

veyer belt superstructure or any surroundings, plus any direct radiation from the transmit antenna **4** to the receiver antenna **6,** will not be identified by the receiver **7** since these signals will not have the correct polarisation for entry into the receive antenna **6.** Once the system is calibrated the receiver **7** will detect, in principle, only those electrical changes in the measurement signal due to the presence of a sample **14** in the system.

The sample **14** will introduce additional phase shift and attenuation in the measurement channel. In a preferred embodiment there is only one receiving antenna but it will be appreciated that there can be more than one receiving antenna.

[0030] In one embodiment, a frequency mixer is used in both reference and measurement channels to measure the phase difference. In another embodiment, the reference signal **8a** goes to an attenuator and phase shifter **3.** The attenuator and phase shifter **3** will be set during calibration so that this channel replicates the electrical characteristics of the measurement channel in the absence of a sample **14** or in the presence of a sample of known characteristics.

[0031] The receiver **7** adds the reference signal **8b** and the measuring signal **10b** in antiphase at the receiver input. The inserted phase shift and the attenuation in the reference channel which produces a null signal at the receiver is recorded. The recorded phase shift and the attenuation is sent to the processor where the calculation of physical parameters such as moisture is done.

[0032] In an apparatus where more than one frequency is used, the method is the same as above and the switch **15** then switches between different frequencies.

[0033] The description above is a description of one embodiment. Generally there are four main ways to perform the measurement:

1. The simplest embodiment would be to use a swept oscillator **1** together with both an electrically controllable (programmable) phase shifter and attenuator 3 in the reference channel. In this embodiment the receiver controlled phase shifter and attenuator **3** are adjusted until the added signals at the receiver input are in 'exact' anti-phase producing a 'null' input signal 4 in Fig.4, at the calibration frequency. The recorded change in both attenuation and phase shift when sample **14** is present is sent to the processor.

2. The source **1** is un-swept but frequency controllable and the reference channel contains only an electrically controllable attenuator **3.** In this case the oscillator frequency and the attenuator **3** are adjusted to produce a null at the receiver **7.** The recorded change in frequency and attenuation are passed to the processor.

3. A swept frequency source **3** is used which permits the frequency responses shown in Fig. 4 to be produced at the receiver. The receiver electronics are more complicated and are required to be able to record the change in shape of this response, which is an indication of the phase change and attenuation change due to the substance being measured. In this case the reference channel's programmable phase shifter and attenuator are not needed since the more sophisticated electronics are providing the requisite phase shift and attenuation information. However, the manually adjusted attenuator and phase shifter **17** in Fig. 3 will still be present to calibrate the system to achieve an exact anti-phase or null input signal **26** in Fig. 4, at a certain frequency, when no sample is present.

4. The source **1** is unswept, and both the attenuation change and the phase shift change caused by the insertion of a sample, is determined directly through separate cross-polar receive channels, one for amplitude and the other for phase. In the amplitude channel, a rectifying diode is used to provide a d.c. signal level which is a measure of the sample attenuation. In the phase channel, a double balanced frequency mixer is used to provide an I.F. (d. c.) signal level which is a measure of the phase change caused by the sample.

[0034] FIGS. 2a and 2b are schematic drawings of one embodiment of the present invention demonstrating a very simple version of an apparatus. The microwave source 1 which can be a swept source generates a timed dependent electrical signal, where a part of the signal is divided at the coupler **2** where part of the signal is used as reference signal 9, while the remaining signal passes to the transmit antenna **4** where part of it is reflected from the polariser **5** and going through the object **14.** This is called the measurement signal **11.**

[0035] FIG. 3 is a schematic drawing of a second exemplary embodiment of an apparatus that can be used with the present invention. This apparatus measures similar to the apparatus in Fig. 2 the moisture and sad content of a sample (tobacco), wherein the sample can be in a rest position or being conveyed on a conveyor belt.

[0036] This apparatus uses two frequencies since it is measuring two different physical parameters, moisture and salt content. Therefore the switch **15** switches between **8** GHz and 12 GHz after receiving a signal from the receiver **7.** Other frequencies can be used for the same results.

[0037] The apparatus includes a microwave radiation source **1.** The swept source **1** receives a signal from the switch **15** before sending a signal to the coupler **2.** The signal from the swept source **1,** once amplified to an appropriate level, is then divided at the coupler **2,** with part going as a reference signal **8a** through a reference channel to the receiver **7,** while the remaining signal

passes to the transmit antenna **4** as the measurement signal **10a.** The signals that go to the two different direction are ideally equal, each part being exactly 50% of the original signal.

[0038] The microwaves are directed at the sample and are transmitted from the transmit antenna **4.** The source **1** is a very high frequency microwave oscillator the frequency of which is changed linearly with time in a repetitive manner over a prescribed bandwidth.

[0039] A part of the transmitted signal **11** passes through the sample **14,** hits the polariser and is reflected back. Another part of the transmitted signal **25** is reflected as the signal hits the sample. That part is received by the co-polarised receive antenna **19** and is used to measure the thickness of the sample **14** by detecting the phase shift of the first reflection. The part that passes through the sample **14** and hits the polariser is received, after reflection and change in polarisation, by the transverse polarised receive antenna **6.**

[0040] The reference signal **8a** goes to a manually adjusted attenuator and phase shifter **17** and then to a programmable/variable attenuator and phase shifter **18.** The manually adjusted attenuator and phase shifter **17** is used to calibrate the signal once the apparatus is set up so as the summed signal is 0 at a certain frequency in the frequency sweep, when there is no object present. When a sample is present, it increases the attenuation and phase shift in the microwaves in the measurement channel and the signal **10b** is weaker as it goes into antenna **6.** Receiver **7** then sends a signal to adjust the programmable/variable attenuator and phase shifter **18** to achieve a summed signal of nullagain. The amount of adjustments is recorded as the measurement values of attenuation and phase of the sample.

[0041] An infra-red thermometer **20** measures the temperature of the sample **14** and sends a signal to the receiver so that measurements of the relative complex permittivity can be corrected for different temperatures.

[0042] The receiver 7 adds the reference signal **8b** and the measuring signal **10b** in antiphase. When phase shift and attenuation **18** is adjusted correctly, a null is detected, meaning that attenuation in **8b** is the same as in **10b.** The phase shift and the attenuation in the reference channel are then recorded. The detected phase shift and the attenuation is sent to the processor where the calculation and conversion of values into meaningful information is done.

[0043] FIG. 4 is a graph showing an example of an electrical signal from receiver **7** used to calculate the ε' and ε'' of a sample. The x-axis represents the frequency sweep of the source and the y-axis shows the strength of the signal. At first, no sample is present and the system is tuned to give response **26.** When sample is present, attenuation of transmitted microwaves increases due to loss in the material, and there will be a phase change. Since the signal is unchanged in the reference channel, the sum of the reference signal and the measurement signal changes when sample is present, and this is shown by response curve **27.** The difference in horizontal direction represents phase change and difference in vertical direction represents attenuation change due to the sample, and these parameters are used to calculate ε' and ε'' according to published formulae.

[0044] Both the wet-mass and the density determination can be based on historic data depending on the object, which can for example be tobacco, wood or corn. Each of these objects may have their own relation between the phase shift and attenuation and the actual moisture content and density. Rather than using formulae, one could choose to collect data from the apparatus and fit to the actual values of moisture and density.

[0045] In Fig. 4 the curve **26** shows a measured signal when there is no sample being measured, as in Fig. 2a. In this case the measured signal is the same as the reference signal, but with different polarisation. Thus, the sum of the reference signal and the measured signal is then 0 at a certain frequency in the sweep. The reference value is then 0 for no moisture present.

[0046] The measuring curve **27** shows when the signal goes through a sample with moisture. In this case the sample reduces or attenuates the signal by 50%. Since the reference signal is unchanged, the sum of the reference, signal and the measured signal is changed by 50% in the vertical direction, which is the attenuation axis. If the sample was pure water, absorbing all microwaves, measurement signal would be attenuated to nothing, and only reference signal would be received, giving a straight line at the attenuation level of the reference signal.

[0047] Furthermore, the curve **27** represents a phase shift in the microwaves for a frequency sweep, which can be seen by the location of the minima of the signal, which has moved to the left from f_0 to f_1. This phase shift is as mentioned before used to calculate the density of the sample.

[0048] From calculating density by using the relative complex permittivity, using the formula for density $\rho = (m_{wet}+m_{dry})/V$ and by knowing the wet mass m_{wet} the dry mass can be calculated if the volume of the object is known. As shown in Fig. 3, the volume can be estimated by means of using the co-polarised receive antenna **19** to measure the thickness of the sample **14**, which can be registered periodically. If the object is being transported on a conveyer belt with a constant speed, the object can be divided into parts with a fixed height and different thickness.

[0049] FIG. 5 shows one embodiment of the polariser, comprised of parallel metallic wires **28** positioned in the horizontal plane of the polarisation plate for rotating at least a part of the transmitted waves. These wires can be supported by a non-reflecting medium **29** such as a plastic material. The bottom layer of the polarization plate can be a reflecting material such as a metallic plate **30.** As the microwaves hits the polarisation plate part of them hits the wires that rotate the polarisation and a part

passes between the wires through the supporting material until it is reflected from the bottom plate **30.** Having the side of the polarisation plate positioned parallel to the line between the transmit antenna **4** and the receive antenna 6 and the two 45° angles **31, 32** equal ensures a 90° rotation in the polarisation of both the incoming microwaves from the transmit antenna 4 and the microwaves reflected from the bottom plate **30** that hit the metallic wires **28** on the way out of the non reflected medium **29.**

[0050] The invention is further illustrated by the following example, which is not intended to be limiting in any way.

Example.

[0051] The following example is based on an experiment that was carried out on 9 samples of tea leaves, where each sample was around 100g, and each with different moisture content, from 5% moisture to 20% moisture. Two swept frequencies were used, one around 8GHz and one around 12GHz. Attenuation was measured in the samples, but not the phase change. The experiment shows that there was a linear relationship between attenuation and actual moisture content of the sample, as can be seen in Fig. 6. The correlation coefficient was high, 0.9914 for the 8GHz frequency and 0.9789 for the 12GHz frequency. The correlation coefficient is a factor from 0 to 1, which represents how well the data points fall on to fitted line.

Claims

1. An apparatus for measuring at least one physical parameter of an object by means of transmitting microwaves towards the object and analysing the reflected microwaves, said apparatus comprising:

- a source for generating a time dependent electrical signal,
- a transmitter positioned in proximity to the object for converting the time dependent electrical signal to microwaves and transmitting the microwaves towards the object,
- a polarizer positioned adjacent to the object and opposite to the transmitter for rotating at least part of the polarisation of the transmitted waves and reflecting a predetermined polarity of the transmitted waves,
- a receiver positioned opposite to the object with respect to the polarizer for receiving the reflected microwaves of predetermined polarity that have passed through the object twice and converting them into an electrical signal,
- wherein said transmitter and said receiver are orthogonally polarized with respect to each other, and
- a computer system for utilizing the electrical signal for calculating the at least one physical parameter of the object.

2. An apparatus according to claim 1, further comprising control electronics for controlling the source.

3. An apparatus according to claim 1 or 2, wherein the polarizer is a plate with a plurality of parallel wires positioned in a horizontal plane of the plate for rotating at least a part of the transmitted waves.

4. An apparatus according to any of the preceding claims, wherein the thickness of the polarizer is ¼ of the wavelength of the microwave.

5. An apparatus according to any of the preceding claims, further comprising a coupler for dividing the electrical signal between the transmitter and the receiver, wherein the part of the electrical signal to the receiver passes trough a reference channel and is used as a reference signal.

6. An apparatus according to any of the preceding claims, wherein the object is being conveyed as the object is being measured.

7. An apparatus according to any of the preceding claims, wherein at least one physical parameter is the moisture content and/or the density of the object.

8. An apparatus according to any of the preceding claims, wherein the receiver is an antenna.

9. An apparatus according to any of the preceding claims, wherein the receiver is a diode.

10. An apparatus according to any of the preceding claims, further comprising a second receiver positioned opposite to the object with respect to the polarizer for receiving at least part of the reflected microwaves.

11. A method for determining at least one physical parameter of an object by means of transmitting a microwave towards the object and measuring the reflection of waves that have passed through the object twice, said method comprising the steps of:

- generating a time dependent first electrical signal and converting at least part of the first electrical signal to polarized microwaves,

- transmitting said polarized microwaves towards the object,
- reflecting the transmitted microwaves by a polarizer positioned adjacent to the object and opposite the transmitter wherein at least part of the polarisation of the reflected microwaves is rotated,
- receiving the rotated part of the reflected microwaves from the polarizer that have passed through the object twice with a polarized receiver positioned opposite to the object and converting the received part of the transmitted wave into an second electrical signal, the receiver being cross-polarized with respect to the transmitter, and
- analysing the second electrical signal and determining at least one physical parameter.

12. A method according to claim 11, wherein a part of the first electrical signal is passed through a reference channel to the receiving means and is used as a reference signal.

13. A method according to claim 11, wherein at a part of the generated microwaves and a part of the received rotated part of the reflected microwaves from the polarizer are fed to a frequency mixer to determine the phase shift between the generated microwaves and the reflected microwaves caused by the object.

14. A method according to any of the claims 11-13, wherein the sum of the second electrical signal and the reference signal is used for determining at least one physical parameter.

15. A method according to any of the claims 11-14, wherein the second electrical signal is used for determining at least one physical parameter.

16. A method according to any of the claims 11-15. further comprising a second receiving means positioned opposite to the object with respect to the polarizer for receiving at least part of the reflected microwaves of predetermined polarity, wherein the received microwaves are converted into an electrical signal and wherein the phase shift of the electrical signal with respect to a reference signal is used to determine the height of the object.

17. A method according to any of the claims 11-16, wherein the attenuation level and the phase shift of the signal is used to calculate the dielectric constant and the loss factor of the object.

18. A method according to claim 17, wherein the dielectric constant and the loss factor of the object are used to calculate the density of the object.

19. A method according to claim 17, wherein the dielectric constant and the loss factor of the object are used to calculate the moisture content of the object.

20. A method according to claim 11, wherein the at feast one physical parameter includes one or more of fat content, salt content, and protein content of said object.

21. A method according to any of the claims 16-20, wherein the volume, the density and the moisture content of the object are used to determine weight of the dry mass of the object.

22. A method according to any of the claims 11-21, wherein the determination of at least the physical parameter of of an object is based on historical data.

Patentansprüche

1. Vorrichtung zum Messen von mindestens einem physikalischen Parameter eines Gegenstandes durch Senden von Mikrowellen zu dem Gegenstand hin und Analysieren der reflektierten Mikrowellen, wobei die Vorrichtung umfasst:

- eine Quelle zum Erzeugen eines zeitabhängigen elektrischen Signals,
- einen Sender, der in der Nähe des Gegenstandes angeordnet ist, zum Umwandeln der zeitabhängigen elektrischen Signale in Mikrowellen und Senden der Mikrowellen zu dem Gegenstand hin,
- einen Polarisator, der dem Gegenstand benachbart und dem Sender entgegengesetzt angeordnet ist, zum Drehen von mindestens einem Teil der Polarisierung der ausgesendeten Wellen und Reflektieren einer vorgegebenen Polarität der ausgesendeten Wellen,
- einen Empfänger, der dem Gegenstand in Bezug auf den Polarisator entgegengesetzt angeordnet ist, zum Empfangen der reflektierten Mikrowellen von vorgegebener Polarität, welche durch den Gegenstand zweimal durchgetreten sind, und Umwandeln derselben in ein elektrisches Signal,
- wobei der Sender und der Empfänger in Bezug aufeinander orthogonal polarisiert sind, und

- ein Rechnersystem zum Verwenden des elektrischen Signals zum Berechnen des mindestens einen physikalischen Parameters des Gegenstandes.

2. Vorrichtung nach Anspruch 1, weiterhin umfassend eine Steuerelektronik zum Steuern der Quelle.

3. Vorrichtung nach Anspruch 1 oder 2, wobei der Polarisator eine Platte mit einer Mehrzahl von parallelen Drähten, die in einer horizontalen Ebene der Platte angeordnet sind, zum Drehen von mindestens einem Teil der ausgesendeten Wellen ist.

4. Vorrichtung nach einem der vorangehenden Ansprüche, wobei die Dicke des Polarisators 1/4 der Wellenlänge der Mikrowelle beträgt.

5. Vorrichtung nach einem beliebigen der vorangehenden Ansprüche, weiterhin umfassend einen Koppler zum Teilen des elektrischen Signals zwischen dem Sender und dem Empfänger, wobei der Teil des elektrischen Signals zu dem Empfänger durch einen Referenzkanal tritt und als Referenzsignal verwendet wird.

6. Vorrichtung nach einem beliebigen der vorangehenden Ansprüche, wobei der Gegenstand transportiert wird, während der Gegenstand gemessen wird.

7. Vorrichtung nach einem beliebigen der vorangehenden Ansprüche, wobei mindestens ein physikalischer Parameter der Feuchtegehalt und/oder die Dichte des Gegenstandes ist.

8. Vorrichtung nach einem beliebigen der vorangehenden Ansprüche, wobei der Empfänger eine Antenne ist.

9. Vorrichtung nach einem beliebigen der vorangehenden Ansprüche, wobei der Empfänger eine Diode ist.

10. Vorrichtung nach einem beliebigen der vorangehenden Ansprüche, weiterhin umfassend einen zweiten Empfänger, der dem Gegenstand in Bezug auf den Polarisator entgegengesetzt angeordnet ist, zum Empfangen von mindestens einem Teil der reflektierten Mikrowellen.

11. Verfahren zum Bestimmen von mindestens einem physikalischen Parameter eines Gegenstandes durch Senden einer Mikrowelle zu dem Gegenstand hin und Messen der Reflexion von Wellen, welche zweimal durch den Gegenstand getreten sind, wobei das Verfahren folgende Schritte umfasst:

- Erzeugen eines zeitabhängigen ersten elektrischen Signals und Umwandeln von mindestens einem Teil des ersten elektrischen Signals in polarisierte Mikrowellen,
- Aussenden der polarisierten Mikrowellen zu dem Gegenstand hin,
- Reflektieren der ausgesendeten Mikrowellen durch einen Polarisator, der dem Gegenstand benachbart und dem Sender entgegengesetzt angeordnet ist, wobei mindestens ein Teil der Polarisierung der reflektierten Mikrowellen gedreht ist,
- Empfangen des gedrehten Teils der reflektierten Mikrowellen von dem Polarisator, welche zweimal durch den Gegenstand getreten sind, wobei ein polarisierter Empfänger dem Gegenstand entgegengesetzt angeordnet ist und den empfangenen Teil der ausgesendeten Welle in ein zweites elektrisches Signal umwandelt, wobei der Empfänger in Bezug auf den Sender kreuzpolarisiert ist, und
- Analysieren des zweiten elektrischen Signals und Bestimmen von mindestens einem physikalischen Parameter.

12. Verfahren nach Anspruch 11, wobei ein Teil des ersten elektrischen Signals durch einen Referenzkanal zu dem Empfangsmittel geführt wird und als Referenzsignal verwendet wird.

13. Verfahren nach Anspruch 11, wobei ein Teil der erzeugten Mikrowellen und ein Teil des empfangenen gedrehten Teils der reflektierten Mikrowellen von dem Polarisator einem Frequenzmischer zugeführt werden, um die Phasenverschiebung zwischen den erzeugten Mikrowellen und den reflektierten Mikrowellen, welche durch den Gegenstand verursacht wird, zu bestimmen.

14. Verfahren nach einem beliebigen der Ansprüche 11-13, wobei die Summe aus dem zweiten elektrischen Signal und dem Referenzsignal zum Bestimmen von mindestens einem physikalischen Parameter verwendet wird.

15. Verfahren nach einem beliebigen der Ansprüche 11-14, wobei das zweite elektrische Signal zum Bestimmen von mindestens einem physikalischen Parameter verwendet wird.

16. Verfahren nach einem beliebigen der Ansprüche 11-15, weiterhin umfassend ein zweites Empfangsmittel, welches in Bezug auf den Polarisator dem Gegenstand entgegengesetzt angeordnet ist, zum

Empfangen von mindestens einem Teil der reflektierten Mikrowellen von vorgegebener Polarität, wobei die empfangenen Mikrowellen in ein elektrisches Signal umgewandelt werden und wobei die Phasenverschiebung des elektrischen Signals in Bezug auf ein Referenzsignal verwendet wird, um die Höhe des Gegenstandes zu bestimmen.

17. Verfahren nach einem beliebigen der Ansprüche 11-16, wobei der Dämpfungspegel und die Phasenverschiebung des Signals verwendet werden, um die dielektrische Konstante und den Verlustfaktor des Gegenstandes zu berechnen.

18. Verfahren nach Anspruch 17, wobei die dielektrische Konstante und der Verlustfaktor des Gegenstandes verwendet werden, um die Dichte des Gegenstandes zu berechnen.

19. Verfahren nach Anspruch 17, wobei die dielektrische Konstante und der Verlustfaktor des Gegenstandes verwendet werden, um den Feuchtegehalt des Gegenstandes zu berechnen.

20. Verfahren nach Anspruch 11, wobei der mindestens eine physikalische Parameter einen oder mehrere aus der Gruppe umfassend Fettgehalt, Salzgehalt und Proteingehalt des Gegenstandes umfasst.

21. Verfahren nach einem beliebigen der Ansprüche 16-20, wobei das Volumen, die Dichte und der Feuchtegehalt des Gegenstandes verwendet werden, um das Gewicht der Trockenmasse des Gegenstandes zu bestimmen.

22. Verfahren nach einem beliebigen der Ansprüche 11-21, wobei die Bestimmung von mindestens einem physikalischen Parameter eines Gegenstandes auf historischen Daten beruht.

Revendications

1. Appareil pour mesurer au moins un paramètre physique d'un objet au moyen de la transmission de micro-ondes vers l'objet et de l'analyse des micro-ondes réfléchies, ledit appareil comprenant :

- une source pour engendrer un signal électrique fonction du temps,
- un transmetteur positionné à proximité de l'objet afin de convertir le signal électrique fonction du temps en micro-ondes et de transmettre les micro-ondes vers l'objet,
- un polariseur en positionnement voisin de l'objet et opposé par rapport au transmetteur afin de réaliser la rotation d'au moins une partie de la polarisation des ondes transmises et de réfléchir une polarité prédéterminée des ondes transmises,
- un récepteur en positionnement opposé à l'objet par rapport au polariseur afin de recevoir les micro-ondes réfléchies de polarité prédéterminée, qui ont traversé l'objet à deux reprises, et afin de les convertir en un signal électrique,
- ledit transmetteur et ledit récepteur étant en polarisation mutuelle orthogonale, et
- un système informatique destiné à utiliser le signal électrique afin de calculer au moins ledit paramètre physique de l'objet.

2. Appareil selon la revendication 1, comprenant en outre une électronique de commande pour commander la source.

3. Appareil selon la revendication 1 ou 2, dans lequel le polariseur est une plaque ayant une pluralité de fils parallèles, positionnés dans un plan horizontal de la plaque pour faire tourner au moins une partie des ondes transmises.

4. Appareil selon l'une quelconque des revendications précédentes, dans lequel l'épaisseur du polariseur est de 1/4 de la longueur d'onde de la micro-onde.

5. Appareil selon l'une quelconque des revendications précédentes, comprenant en outre un coupleur pour diviser le signal électrique entre le transmetteur et le récepteur, dans lequel la partie du signal électrique vers le récepteur traverse un canal de référence et est utilisée comme signal de référence.

6. Appareil selon l'une quelconque des revendications précédentes, dans lequel l'objet est déplacé au fur et à mesure que l'objet est mesuré.

7. Appareil selon l'une quelconque des revendications précédentes, dans lequel au moins un paramètre physique est la teneur en humidité et/ou la densité de l'objet.

8. Appareil selon l'une quelconque des revendications précédentes, dans lequel le récepteur est une antenne.

9. Appareil selon l'une quelconque des revendications précédentes, dans lequel le récepteur est une diode.

10. Appareil selon l'une quelconque des revendications précédentes, comprenant en outre un second ré-

cepteur positionné à l'opposé de l'objet par rapport au polariseur, pour recevoir au moins une partie des micro-ondes réfléchies.

11. Procédé pour déterminer au moins un paramètre physique d'un objet au moyen de la transmission d'une micro-onde vers l'objet et de la mesure de la réflexion d'ondes qui ont traversé l'objet deux fois, ledit procédé comprenant les étapes suivantes :

- générer un premier signal électrique fonction du temps et convertir au moins une partie du premier signal électrique en micro-ondes polarisées,
- transmettre lesdites micro-ondes polarisées vers l'objet,
- réfléchir les micro-ondes transmises, par un polariseur positionné au voisinage de l'objet et à l'opposé du transmetteur dans lequel on fait tourner au moins une partie de la polarisation des micro-ondes réfléchies,
- recevoir la partie ainsi déviée en rotation, des micro-ondes réfléchies provenant du polariseur et ayant traversé l'objet deux fois, sur un récepteur polarisé, en positionnement opposé à l'objet, et ensuite convertir la partie reçue de l'onde transmise en un second signal électrique, le récepteur étant polarisé transversalement par rapport au transmetteur, et
- analyser le second signal électrique et déterminer au moins un paramètre physique.

12. Procédé selon la revendication 11, dans lequel une partie du premier signal électrique traverse un canal de référence vers le moyen de réception et est utilisé comme signal de référence.

13. Procédé selon la revendication 11, dans lequel une partie des micro-ondes générées ainsi qu'une partie de la partie, soumise à rotation et reçue, des micro-ondes réfléchies, provenant du polariseur, sont alimentées vers un dispositif de mixage de fréquences afin de déterminer le déphasage entre les micro-ondes générées et les micro-ondes réfléchies provoquées par l'objet.

14. Procédé selon l'une quelconque des revendications 11-13, dans lequel la somme du second signal électrique et du signal de référence est utilisée pour déterminer au moins un paramètre physique.

15. Procédé selon l'une quelconque des revendications 11-14, dans lequel le second signal électrique est utilisé pour déterminer au moins un paramètre physique.

16. Procédé selon l'une quelconque des revendications 11-15, comprenant en outre un second moyen de réception situé en positionnement opposé à l'objet par rapport au polariseur pour recevoir au moins une partie des micro-ondes réfléchies de polarité prédéterminée, dans lequel les micro-ondes reçues sont converties en un signal électrique et dans lequel le déphasage du signal électrique par rapport à un signal de référence est utilisé afin de déterminer la hauteur de l'objet.

17. Procédé selon l'une quelconque des revendications 11-16, dans lequel le niveau d'atténuation et le déphasage du signal sont utilisés afin de calculer la constante diélectrique et le coefficient de pertes de l'objet.

18. Procédé selon la revendication 17, dans lequel la constante diélectrique et le coefficient de pertes sont utilisés afin de calculer la densité de l'objet.

19. Procédé selon la revendication 17, dans lequel la constante diélectrique et le coefficient de pertes sont utilisés afin de calculer la teneur en humidité de l'objet.

20. Procédé selon la revendication 11, dans lequel au moins un paramètre physique inclut une ou plusieurs teneurs parmi la teneur en matières grasses, la teneur en sels et la teneur en protéines dudit objet.

21. Procédé selon l'une quelconque des revendications 16-20, dans lequel le volume, la densité et la teneur en humidité de l'objet sont utilisés afin de déterminer le poids de la masse sèche de l'objet.

22. Procédé selon l'une quelconque des revendications 11-21, dans lequel la détermination d'au moins un paramètre physique d'un objet est basée sur des données historiques.

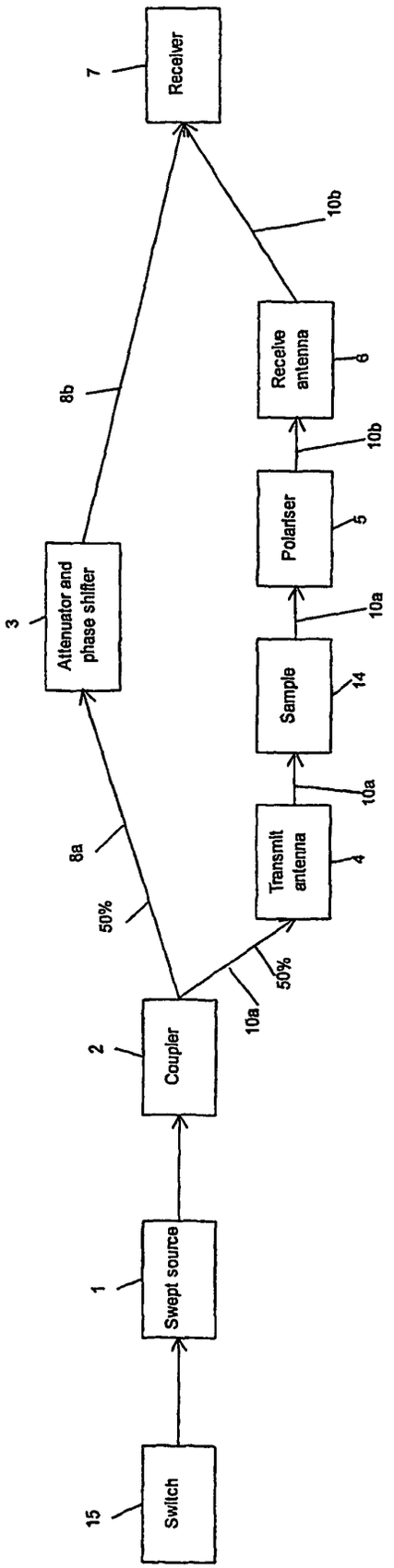

Receiver
7
10b
Receive antenna
6
8b
10b
Polariser
5
Attenuator and phase shifter
3
10a
Sample
14
10a
Transmit antenna
4
8a
50%
50%
10a
Coupler
2
Swept source
1
Switch
15

FIG. 1

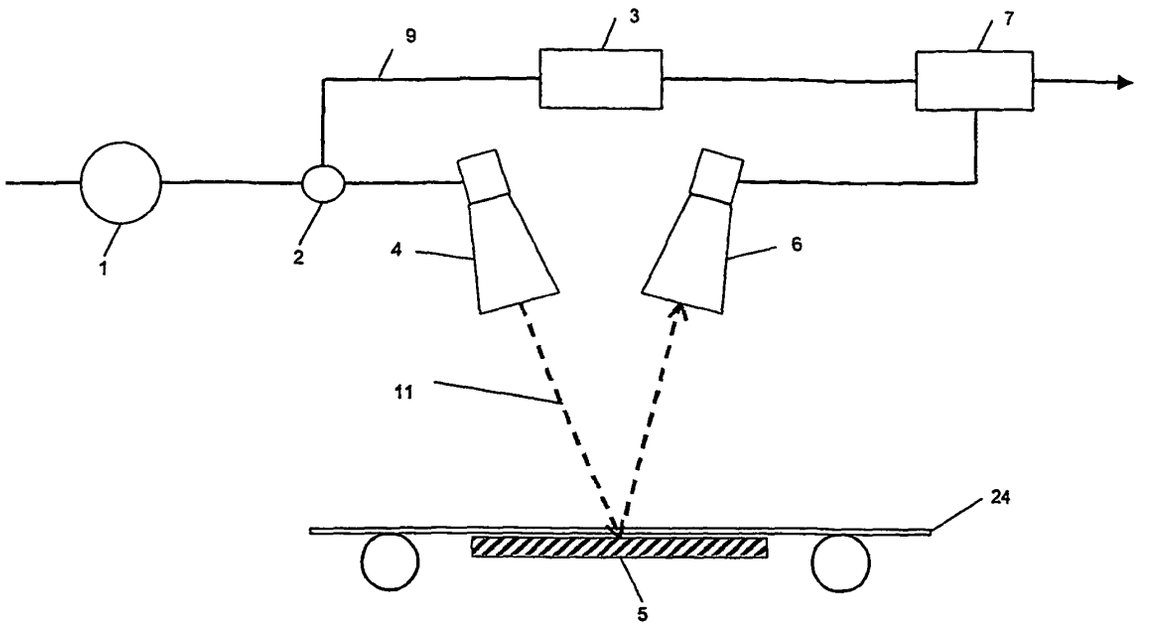


FIG. 2a

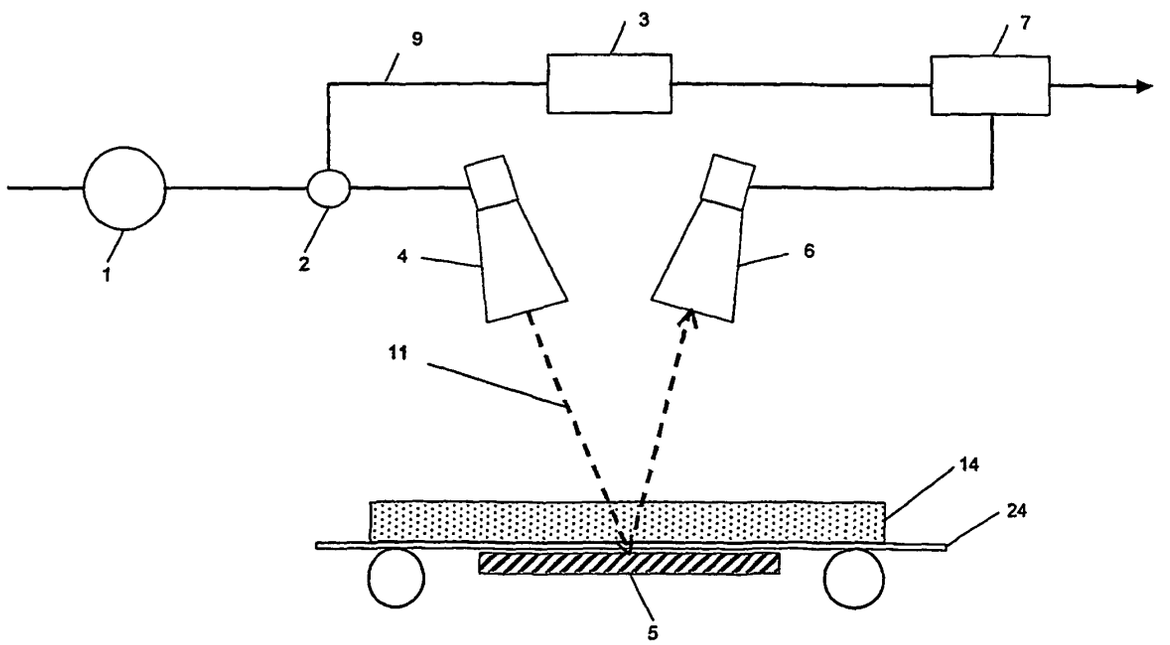


FIG. 2b

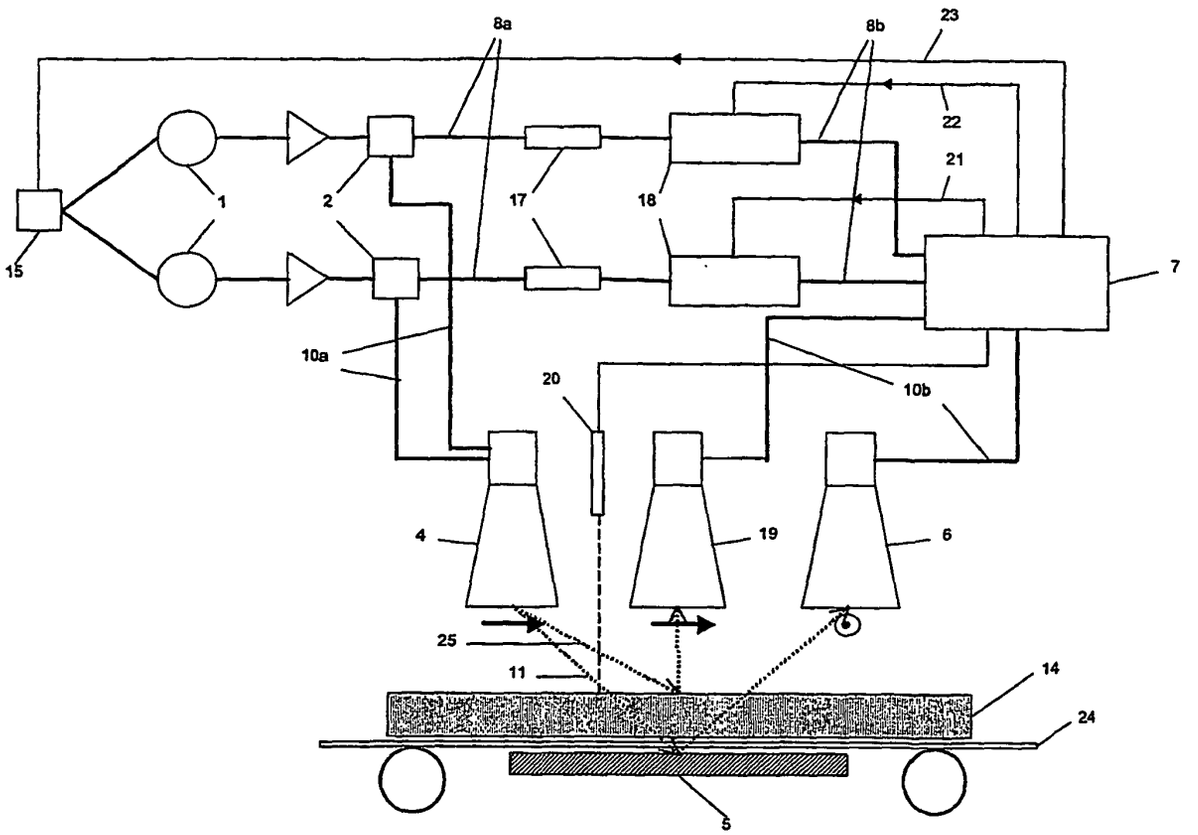


FIG. 3

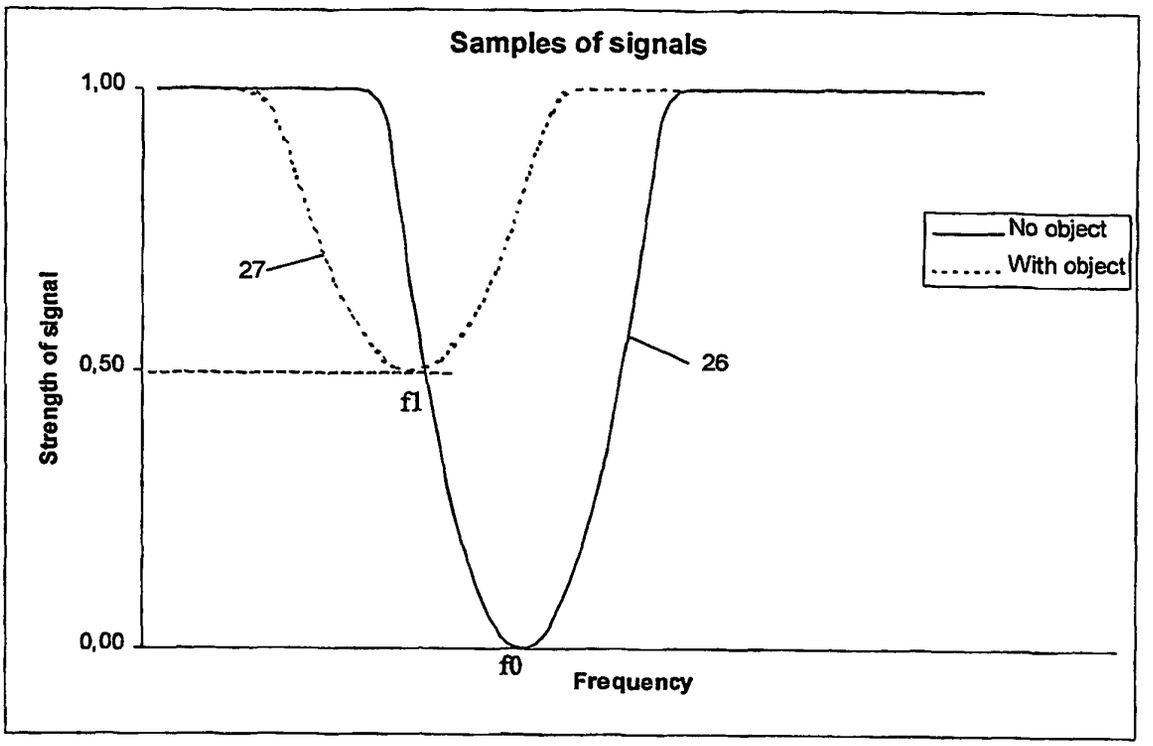

Samples of signals
1,00
0,50
0,00
Strength of signal
27
26
f1
f0
Frequency
No object
With object

FIG. 4

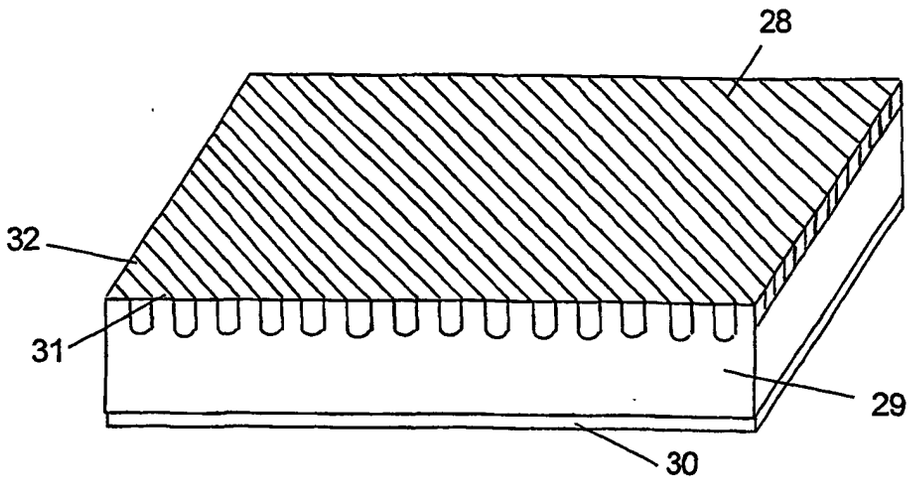
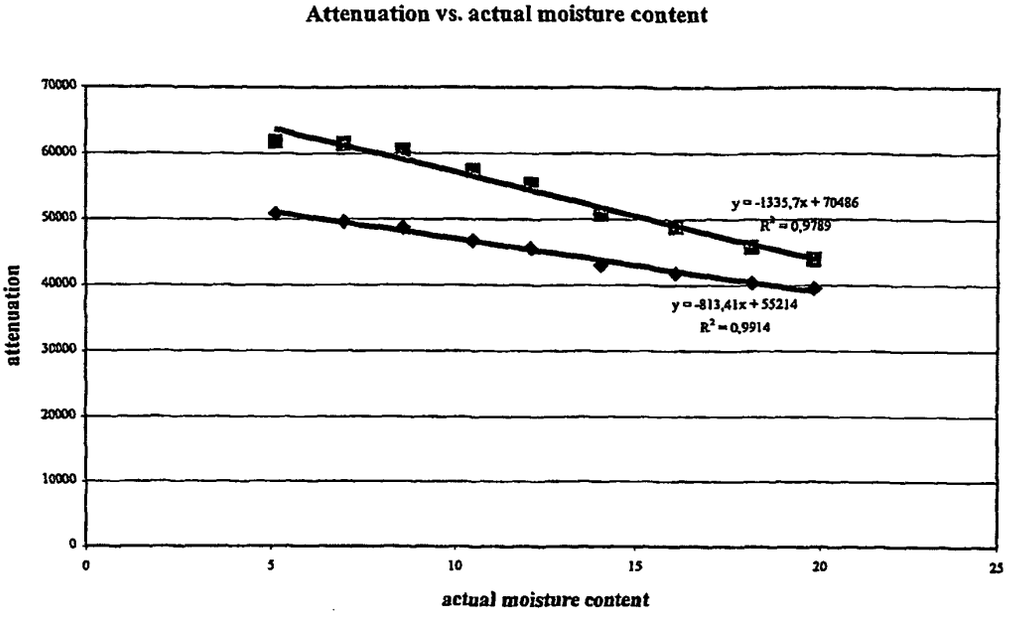


FIG. 5



Upper line is the 12GHz frequency attenuation in the sample, and the lower line is the 8GHz frequency attenuation.

FIG. 6